

6.3.3 Physical random-access channel

6.3.3.1 Sequence generation

The set of random-access preambles $x_{u,v}(n)$ shall be generated according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod L_{RA})$$

$$x_u(i) = e^{-j \frac{2\pi i(i+1)}{L_{RA}}}, i = 0, 1, \dots, L_{RA} - 1$$

from which the frequency-domain representation shall be generated according to

$$y_{u,v}(n) = \sum_{m=0}^{L_{RA}-1} x_{u,v}(m) \cdot e^{-j \frac{2\pi mn}{L_{RA}}}$$

where $L_{RA} = 839$ or $L_{RA} = 139$ depending on the PRACH preamble format as given by Tables 6.3.3.1-1 and 6.3.3.1-2.

There are 64 preambles defined in each time-frequency PRACH occasion, enumerated in increasing order of first increasing cyclic shift C_v of a logical root sequence, and then in increasing order of the logical root sequence index, starting with the index obtained from the higher-layer parameter *prach-RootSequenceIndex*. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic; the logical index 0 is consecutive to 837 when $L_{RA} = 839$ and is consecutive to 137 when $L_{RA} = 139$. The sequence number u is obtained from the logical root sequence index according to Tables 6.3.3.1-3 and 6.3.3.1-4.

The cyclic shift C_v is given by

$$C_v = \begin{cases} vN_{CS} & v = 0, 1, \dots, \lfloor L_{RA}/N_{CS} \rfloor - 1, N_{CS} \neq 0 & \text{for unrestricted sets} \\ 0 & N_{CS} = 0 & \text{for unrestricted sets} \\ \lfloor \frac{d_{start} \lfloor v/n_{shift}^{RA} \rfloor + (v \bmod n_{shift}^{RA})N_{CS}}{d_{start} + (v-w)N_{CS}} \rfloor & v = 0, 1, \dots, w-1 & \text{for restricted sets type A and B} \\ \lfloor \frac{d_{start} + (v-w)\bar{n}_{shift}^{RA}}{d_{start} + (v-w-\bar{n}_{shift}^{RA})N_{CS}} \rfloor & v = w, \dots, w + \bar{n}_{shift}^{RA} - 1 & \text{for restricted sets type B} \\ \lfloor \frac{d_{start} + (v-w-\bar{n}_{shift}^{RA})N_{CS}}{d_{start} + (v-w-\bar{n}_{shift}^{RA})N_{CS}} \rfloor & v = w + \bar{n}_{shift}^{RA}, \dots, w + \bar{n}_{shift}^{RA} + \bar{n}_{shift}^{RA} - 1 & \text{for restricted sets type B} \end{cases}$$

$$w = \lfloor \frac{n_{shift}^{RA} n_{group}^{RA}}{\bar{n}_{shift}^{RA}} \rfloor$$

where N_{CS} is given by Tables 6.3.3.1-5 to 6.3.3.1-7, the higher-layer parameter *restrictedSetConfig* determines the type of restricted sets (unrestricted, restricted type A, restricted type B), and Tables 6.3.3.1-1 and 6.3.3.1-2 indicate the type of restricted sets supported for the different preamble formats.

The variable d_u is given by

$$d_u = \begin{cases} q & 0 \leq q < L_{RA}/2 \\ L_{RA} - q & \text{otherwise} \end{cases}$$

where q is the smallest non-negative integer that fulfils $(qu) \bmod L_{RA} = 1$. The parameters for restricted sets of cyclic shifts depend on d_u .

For restricted set type A, the parameters are given by:

- for $N_{CS} \leq d_u < L_{RA}/3$

$$n_{\text{shift}}^{\text{RA}} = \lfloor d_u / N_{CS} \rfloor$$

$$d_{\text{start}} = 2d_u + n_{\text{shift}}^{\text{RA}} N_{CS}$$

$$n_{\text{group}}^{\text{RA}} = \lfloor L_{RA} / d_{\text{start}} \rfloor$$

$$\bar{n}_{\text{shift}}^{\text{RA}} = \max(\lfloor (L_{RA} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0)$$

- for $L_{RA}/3 \leq d_u \leq (L_{RA} - N_{CS})/2$

$$n_{\text{shift}}^{\text{RA}} = \lfloor (L_{RA} - 2d_u) / N_{CS} \rfloor$$

$$d_{\text{start}} = L_{RA} - 2d_u + n_{\text{shift}}^{\text{RA}} N_{CS}$$

$$n_{\text{group}}^{\text{RA}} = \lfloor d_u / d_{\text{start}} \rfloor$$

$$\bar{n}_{\text{shift}}^{\text{RA}} = \min(\max(\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0), n_{\text{shift}}^{\text{RA}})$$

For restricted set type B, the parameters are given by:

- for $N_{CS} \leq d_u < L_{RA}/5$

$$n_{\text{shift}}^{\text{RA}} = \lfloor d_u / N_{CS} \rfloor$$

$$d_{\text{start}} = 4d_u + n_{\text{shift}}^{\text{RA}} N_{CS}$$

$$n_{\text{group}}^{\text{RA}} = \lfloor L_{RA} / d_{\text{start}} \rfloor$$

$$\bar{n}_{\text{shift}}^{\text{RA}} = \max(\lfloor (L_{RA} - 4d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0)$$

- for $L_{RA}/5 \leq d_u \leq (L_{RA} - N_{CS})/4$

$$n_{\text{shift}}^{\text{RA}} = \lfloor (L_{RA} - 4d_u) / N_{CS} \rfloor$$

$$d_{\text{start}} = L_{RA} - 4d_u + n_{\text{shift}}^{\text{RA}} N_{CS}$$

$$n_{\text{group}}^{\text{RA}} = \lfloor d_u / d_{\text{start}} \rfloor$$

$$\bar{n}_{\text{shift}}^{\text{RA}} = \min(\max(\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0), n_{\text{shift}}^{\text{RA}})$$

- for $(L_{RA} + N_{CS})/4 \leq d_u < 2L_{RA}/7$

$$\begin{aligned}
n_{\text{shift}}^{\text{RA}} &= \lfloor (4d_u - L_{RA})/N_{CS} \rfloor \\
d_{\text{start}} &= 4d_u - L_{RA} + n_{\text{shift}}^{\text{RA}} N_{CS} \\
\bar{d}_{\text{start}} &= L_{RA} - 3d_u + n_{\text{group}}^{\text{RA}} d_{\text{start}} + \bar{n}_{\text{shift}}^{\text{RA}} N_{CS} \\
\bar{\bar{d}}_{\text{start}} &= L_{RA} - 2d_u + n_{\text{group}}^{\text{RA}} d_{\text{start}} + \bar{\bar{n}}_{\text{shift}}^{\text{RA}} N_{CS} \\
n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{\text{RA}} &= \max(\lfloor (L_{RA} - 3d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0) \\
\bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= \lfloor \min(d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}, 4d_u - L_{RA} - \bar{n}_{\text{shift}}^{\text{RA}} N_{CS}) / N_{CS} \rfloor \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= \lfloor ((1 - \min(1, \bar{n}_{\text{shift}}^{\text{RA}}))(d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) + \min(1, \bar{n}_{\text{shift}}^{\text{RA}})(4d_u - L_{RA} - \bar{n}_{\text{shift}}^{\text{RA}} N_{CS})) / N_{CS} \rfloor - \bar{\bar{n}}_{\text{shift}}^{\text{RA}}
\end{aligned}$$

- for $2L_{RA}/7 \leq d_u \leq (L_{RA} - N_{CS})/3$

$$\begin{aligned}
n_{\text{shift}}^{\text{RA}} &= \lfloor (L_{RA} - 3d_u) / N_{CS} \rfloor \\
d_{\text{start}} &= L_{RA} - 3d_u + n_{\text{shift}}^{\text{RA}} N_{CS} \\
\bar{d}_{\text{start}} &= d_u + n_{\text{group}}^{\text{RA}} d_{\text{start}} + \bar{n}_{\text{shift}}^{\text{RA}} N_{CS} \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{\text{RA}} &= \max(\lfloor (4d_u - L_{RA} - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0) \\
\bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= \lfloor \min(d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}, L_{RA} - 3d_u - \bar{n}_{\text{shift}}^{\text{RA}} N_{CS}) / N_{CS} \rfloor \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= 0
\end{aligned}$$

- for $(L_{RA} + N_{CS})/3 \leq d_u < 2L_{RA}/5$

$$\begin{aligned}
n_{\text{shift}}^{\text{RA}} &= \lfloor (3d_u - L_{RA}) / N_{CS} \rfloor \\
d_{\text{start}} &= 3d_u - L_{RA} + n_{\text{shift}}^{\text{RA}} N_{CS} \\
\bar{d}_{\text{start}} &= 0 \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{\text{RA}} &= \max(\lfloor (L_{RA} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0) \\
\bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= 0 \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= 0
\end{aligned}$$

- for $2L_{RA}/5 \leq d_u \leq (L_{RA} - N_{CS})/2$

$$n_{\text{shift}}^{\text{RA}} = \lfloor (L_{RA} - 2d_u)/N_{CS} \rfloor$$

$$d_{\text{start}} = 2(L_{RA} - 2d_u) + n_{\text{shift}}^{\text{RA}} N_{CS}$$

$$\bar{d}_{\text{start}} = 0$$

$$\bar{\bar{d}}_{\text{start}} = 0$$

$$n_{\text{group}}^{\text{RA}} = \lfloor (L_{RA} - d_u)/d_{\text{start}} \rfloor$$

$$\bar{n}_{\text{shift}}^{\text{RA}} = \max(\lfloor (3d_u - L_{RA} - n_{\text{group}}^{\text{RA}} d_{\text{start}})/N_{CS} \rfloor, 0)$$

$$\bar{\bar{n}}_{\text{shift}}^{\text{RA}} = 0$$

$$\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} = 0$$

For all other values of d_u , there are no cyclic shifts in the restricted set.

Table 6.3.3.1-1: PRACH preamble formats for $L_{RA} = 839$ and $\Delta f^{\text{RA}} \in \{1.25, 5\}$ kHz .

Format	L_{RA}	Δf^{RA}	N_u	N_{CP}^{RA}	Support for restricted sets
0	839	1.25 kHz	24576κ	3168κ	Type A, Type B
1	839	1.25 kHz	$2 \cdot 24576\kappa$	21024κ	Type A, Type B
2	839	1.25 kHz	$4 \cdot 24576\kappa$	4688κ	Type A, Type B
3	839	5 kHz	$4 \cdot 6144\kappa$	3168κ	Type A, Type B

Table 6.3.3.1-2: Preamble formats for $L_{RA} = 139$ and $\Delta f^{\text{RA}} = 15 \cdot 2^\mu$ kHz where $\mu \in \{0, 1, 2, 3\}$.

Format	L_{RA}	Δf^{RA}	N_u	N_{CP}^{RA}	Support for restricted sets
A1	139	$15 \cdot 2^\mu$ kHz	$2 \cdot 2048\kappa \cdot 2^{-\mu}$	$288\kappa \cdot 2^{-\mu}$	-
A2	139	$15 \cdot 2^\mu$ kHz	$4 \cdot 2048\kappa \cdot 2^{-\mu}$	$576\kappa \cdot 2^{-\mu}$	-
A3	139	$15 \cdot 2^\mu$ kHz	$6 \cdot 2048\kappa \cdot 2^{-\mu}$	$864\kappa \cdot 2^{-\mu}$	-
B1	139	$15 \cdot 2^\mu$ kHz	$2 \cdot 2048\kappa \cdot 2^{-\mu}$	$216\kappa \cdot 2^{-\mu}$	-
B2	139	$15 \cdot 2^\mu$ kHz	$4 \cdot 2048\kappa \cdot 2^{-\mu}$	$360\kappa \cdot 2^{-\mu}$	-
B3	139	$15 \cdot 2^\mu$ kHz	$6 \cdot 2048\kappa \cdot 2^{-\mu}$	$504\kappa \cdot 2^{-\mu}$	-
B4	139	$15 \cdot 2^\mu$ kHz	$12 \cdot 2048\kappa \cdot 2^{-\mu}$	$936\kappa \cdot 2^{-\mu}$	-
C0	139	$15 \cdot 2^\mu$ kHz	$2048\kappa \cdot 2^{-\mu}$	$1240\kappa \cdot 2^{-\mu}$	-
C2	139	$15 \cdot 2^\mu$ kHz	$4 \cdot 2048\kappa \cdot 2^{-\mu}$	$2048\kappa \cdot 2^{-\mu}$	-